U N I V E R S I T Y O F C A L I F O R N I A

UC CEIN Center for Environmental Implications of Nanotechnology

Multidisciplinary Approaches and Insights into the Ecotoxicology of Engineered Nanomaterials by the UC CEIN

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Bren School, UCSB

UC CEIN

UCSB

University of California Los Angeles, Santa Barbara, Davis, Riverside; Columbia University, NY; University of Texas; University of New Mexico; Molecular Foundry-Lawrence Berkeley National Laboratory

Foundation Institute for Materials Science, University Bremen, Germany; University College Dublin; Nanyang Technological University; Cardiff University Wales, University of British Columbia; Universitat Rovira i Virgili, Spain

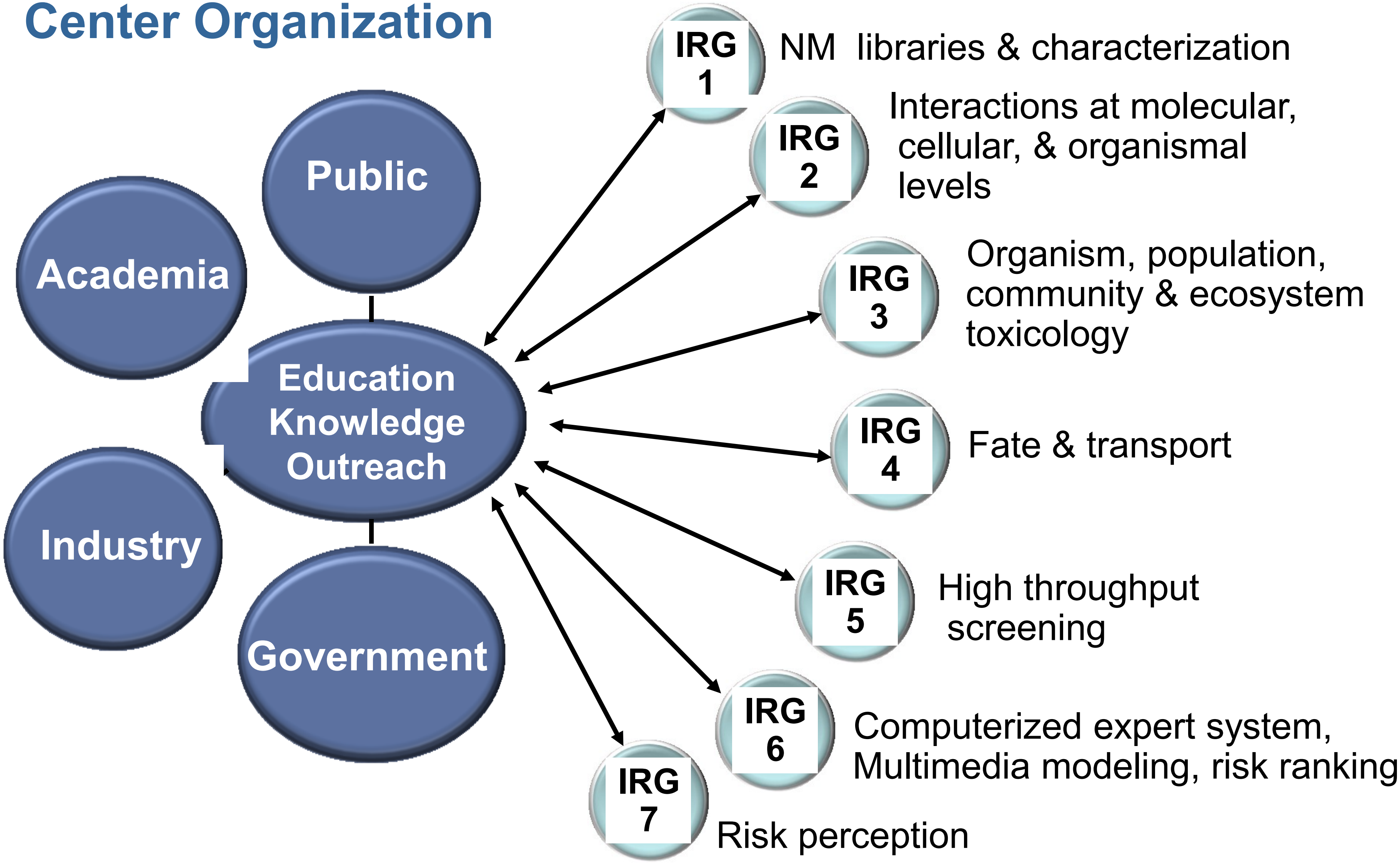
Mission of the UC CEIN

The mission of the UC CEIN is to insure that
nanotechnology is introduced **and** ***implemented***
in a responsible and
environmentally-compatible manner
to allow the US and the International community to leverage the benefits of nanotechnology for global economic and social benefit.

Goals of the UC CEIN

- Develop a **predictive scientific model** that links **bio-physicochemical interactions** at cellular and organism level to effects on populations, ecosystems and **at different trophic levels** in the environment
- Develop compositional and **combinatorial ENM libraries** to demonstrate how key physicochemical properties determine fate and transport as well as a wide range of interactions at the nano-bio interface
- Develop **high content and high throughput screening** to perform hazard ranking that prioritizes and facilitates mesocosm studies in terrestrial, seawater and freshwater environments
- Develop a **computational expert system** that integrates data generation in above environments for quantitative property-activity relationships, multimedia modeling and risk ranking
- Utilize above knowledge domains to **inform the public, academia, industry and government agencies** how nanotechnology can be safely implemented in the environment

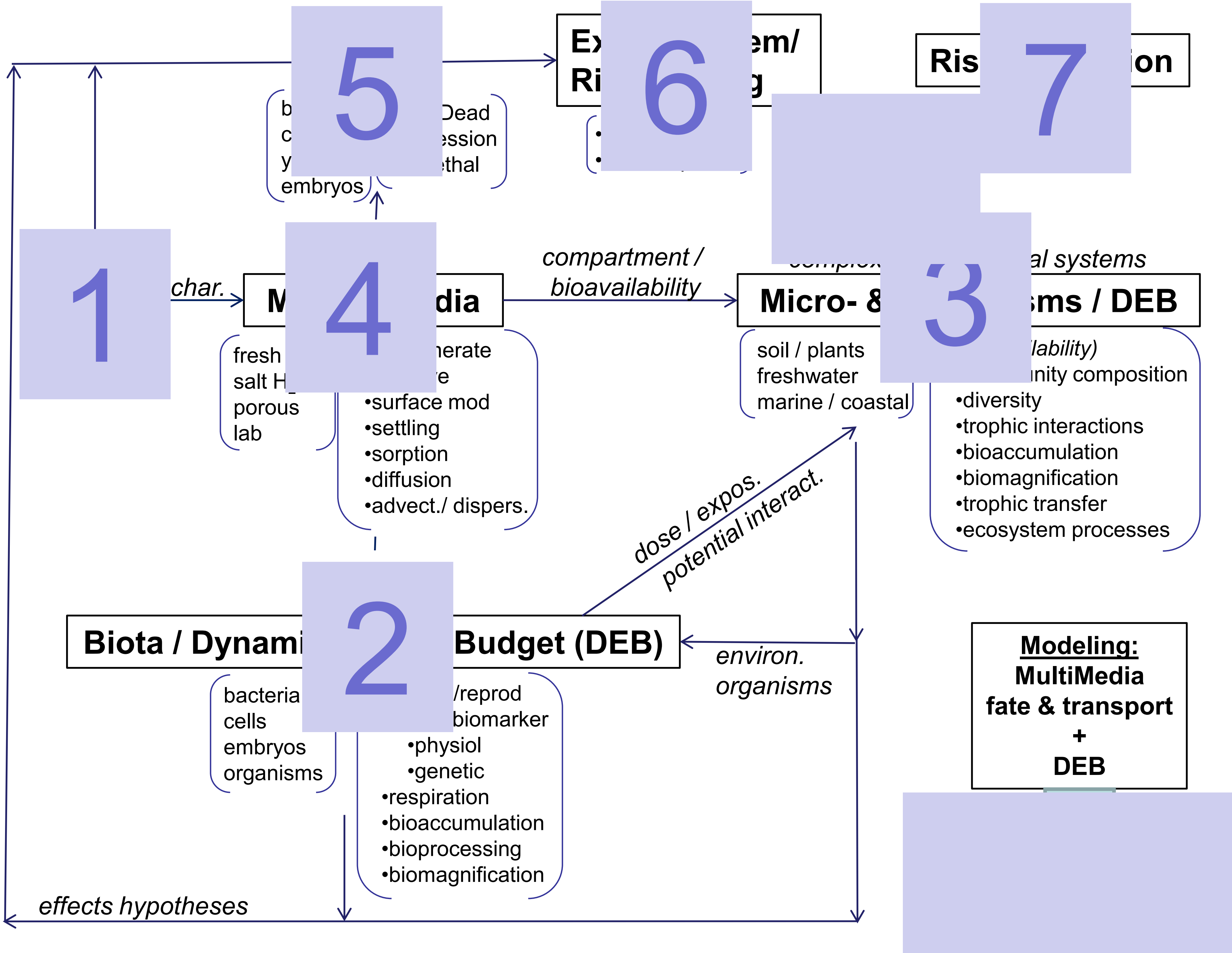
Center Organization




Terrestrial

Freshwater

Marine / Coastal



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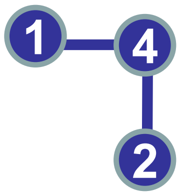
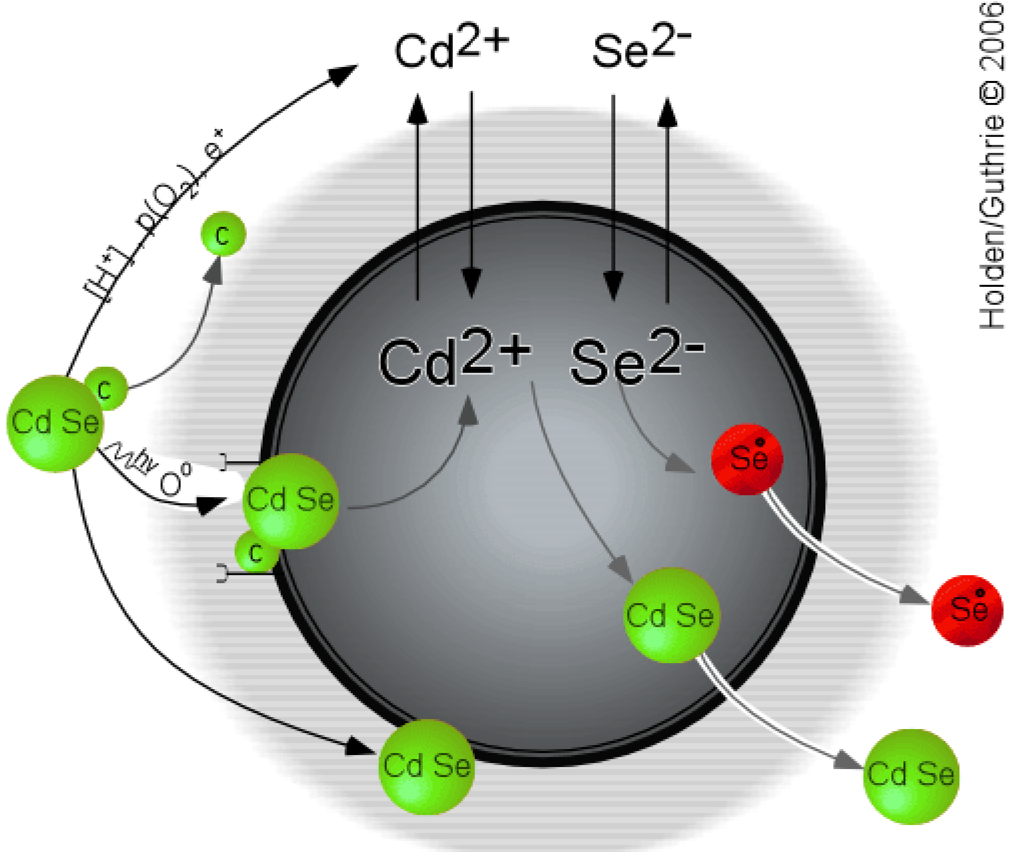
Modeling:
MultiMedia
fate & transport
+
DEB

Potential Effects of CdSe Quantum Dots to Microbes

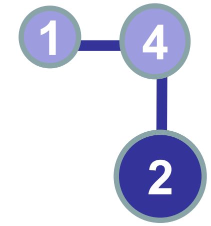


- CdSe QDs
  - Lab-synthesized (Rogach *et* al. 2000)
  - 5 nm, "bare"
  - citrate-stabilized
- Lab media (fully-dispersed)
  - dissolution studied
- Biota
  - *Pseudomonas*
    - growth, damage
    - bioaccum., bioprocess.
    - DEB
  - ***Tetrahymena***
    - **growth, inhibition**
    - **biomagnification**



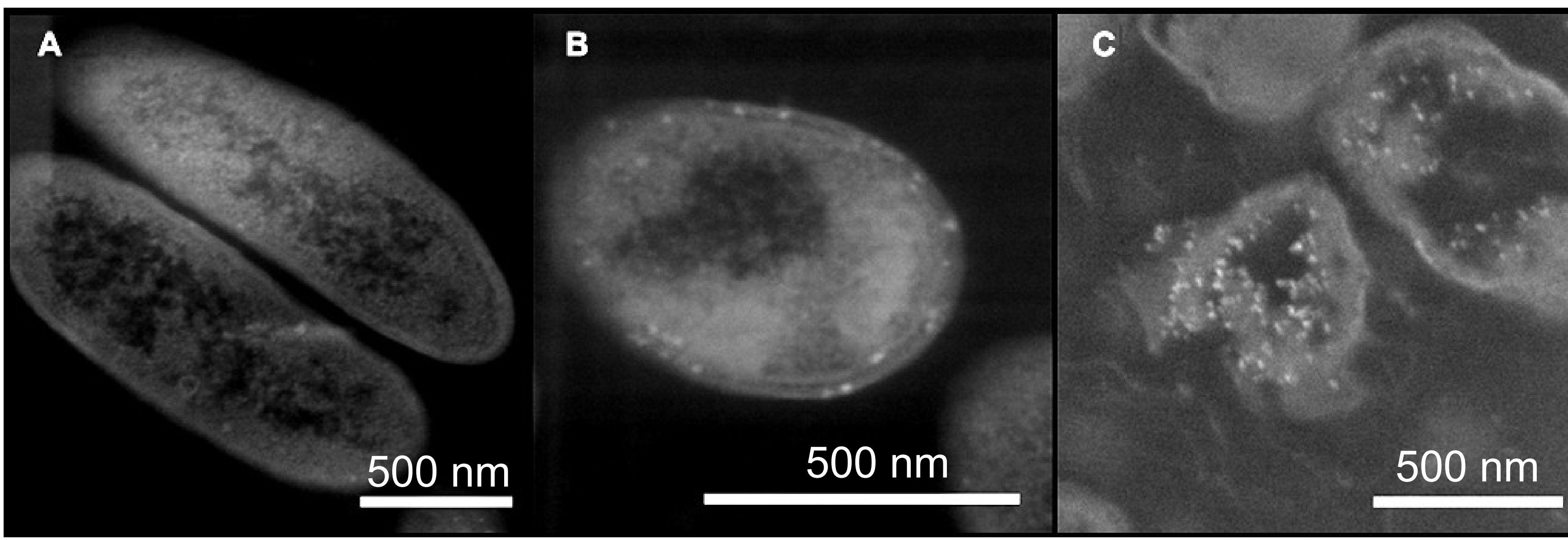
(Nadeau, J. L., J. Priester, G. D. Stucky, P. A. Holden. 2008. *In* Grassian, V. H. "Nanoscience and Nanotechnology: Environmental and Health Impacts")

CdSe QDs Bioaccumulate & Damage Bacteria



- QDs only partially dissolve in growth media
- nanoparticle effect on *Pseudomonas* growth rate
- enhanced cellular ROS appear w/ QDs
- exceeded effects of Cd(II), beyond a threshold

Control | Cd acetate –treated | CdSe QD –treated



(Priester et al. ES&T 2009)

Dynamic Energy Budget (DEB) Model Operationalizes Bacterial Responses to Cd(II) Exposure

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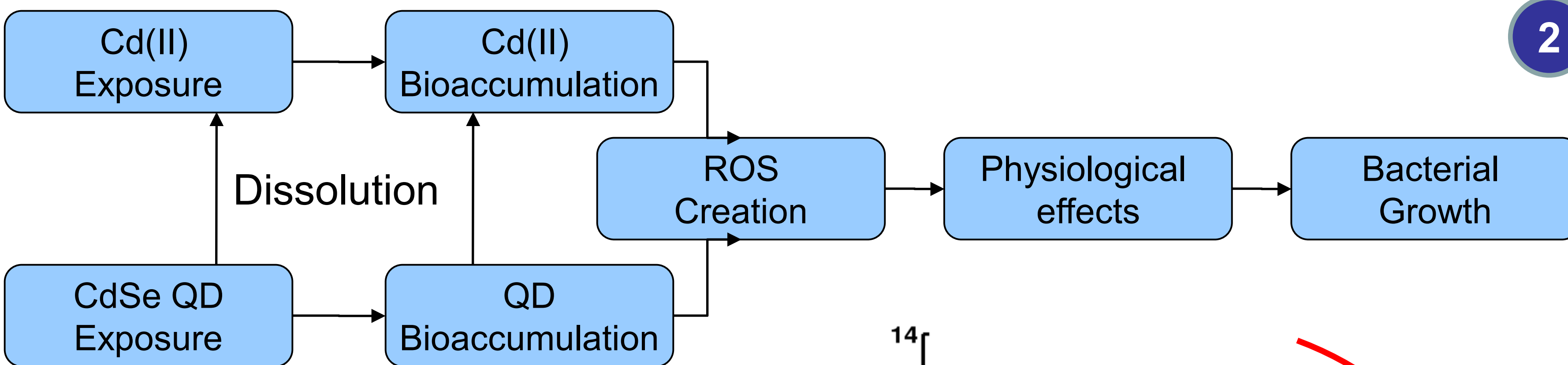
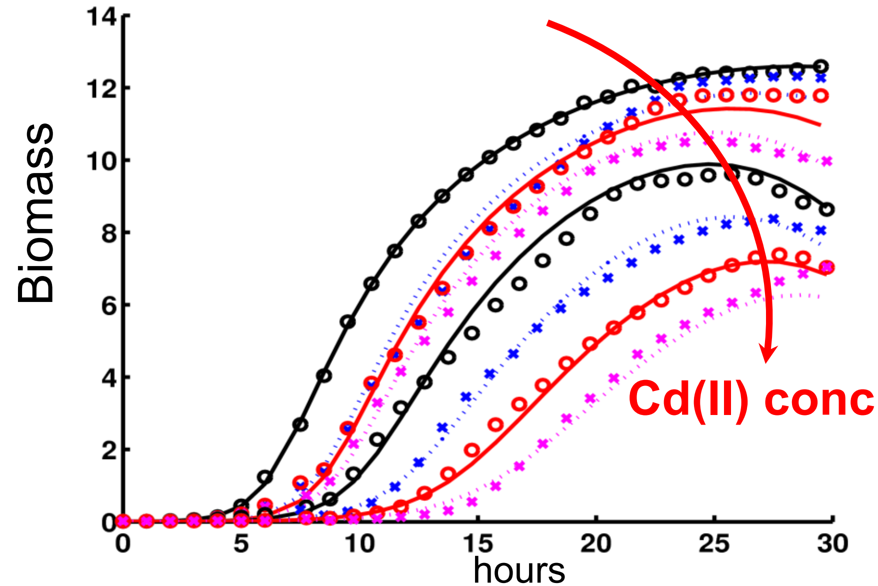


Bacterial DEB model extended to inter-relate exposure, bioaccumulation, production of damage-inducing compounds and bacterial population growth.



(In preparation: Klanjscek, Nisbet , Priester , Holden)

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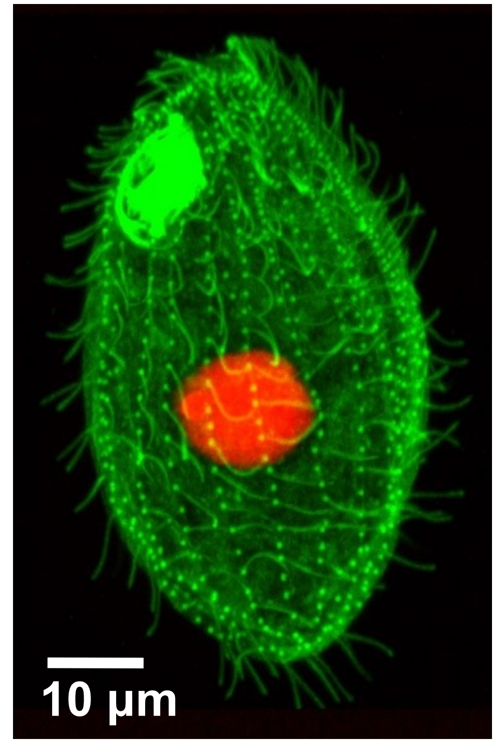
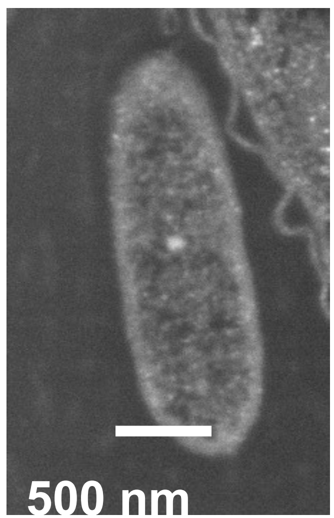
Predator-Prey Study

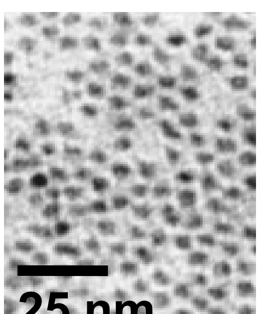


Imaged by Jacek Gaertig

Tetrahymena



Pseudomonas



CdSe QDs

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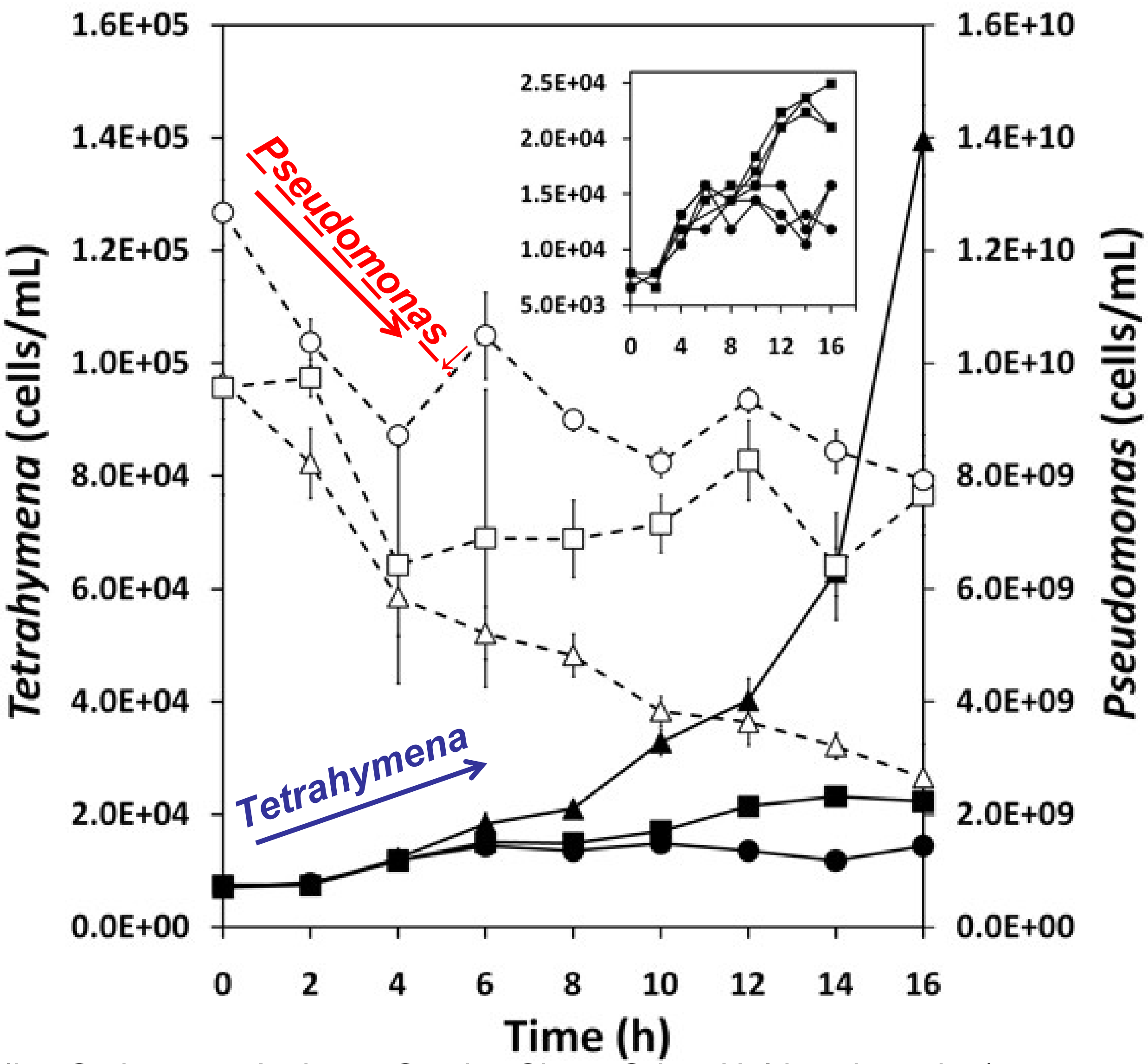

(Werlin, Priester, Mielke, Stoimenov, Jackson, Stucky, Cherr, Orias, Holden, *in review*)

1 4 2

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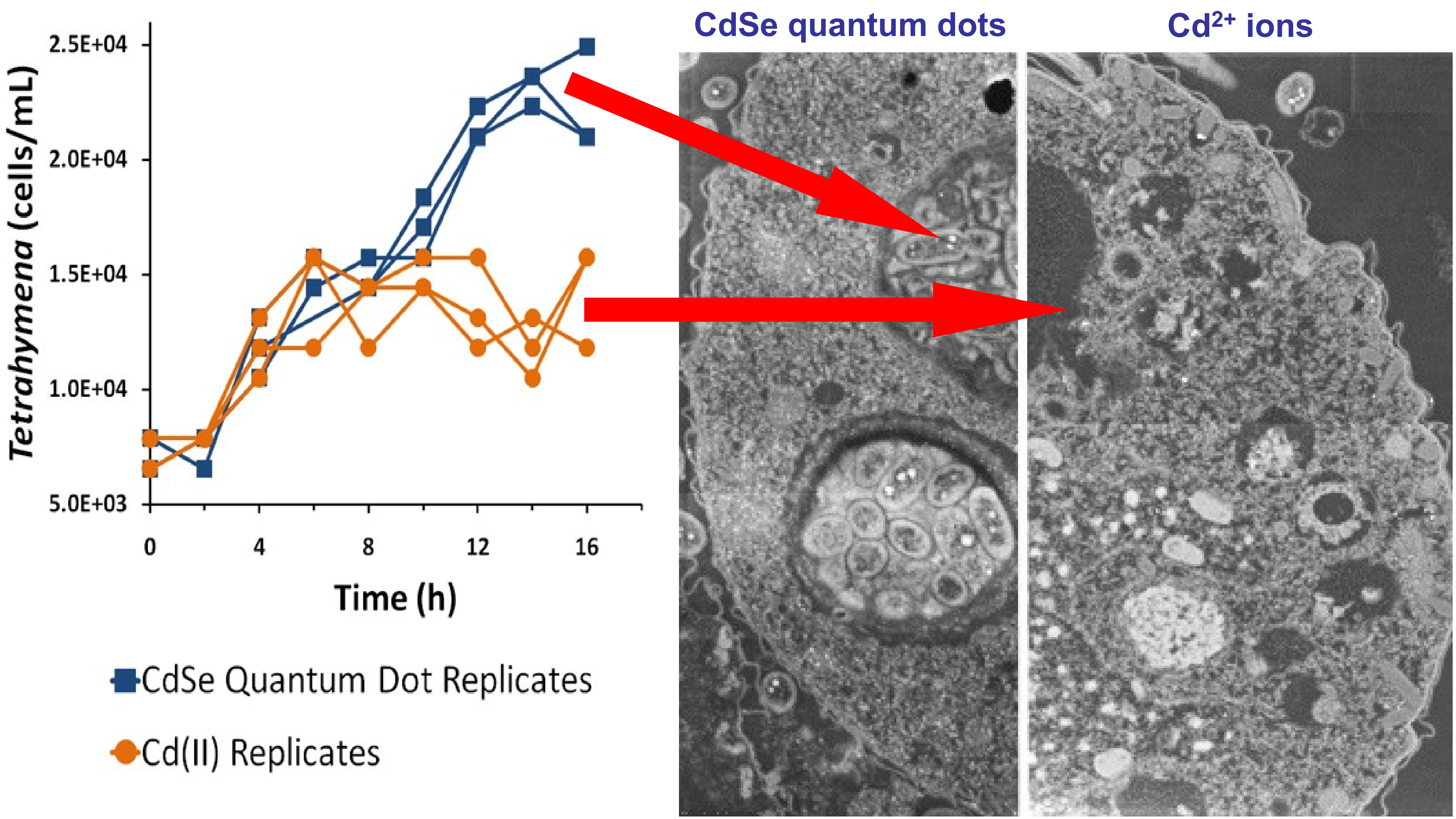
QDs impede digestion

1 4 2



(Werlin, Priester, Mielke, Stoimenov, Jackson, Stucky, Cherr, Orias, Holden, *in review*)

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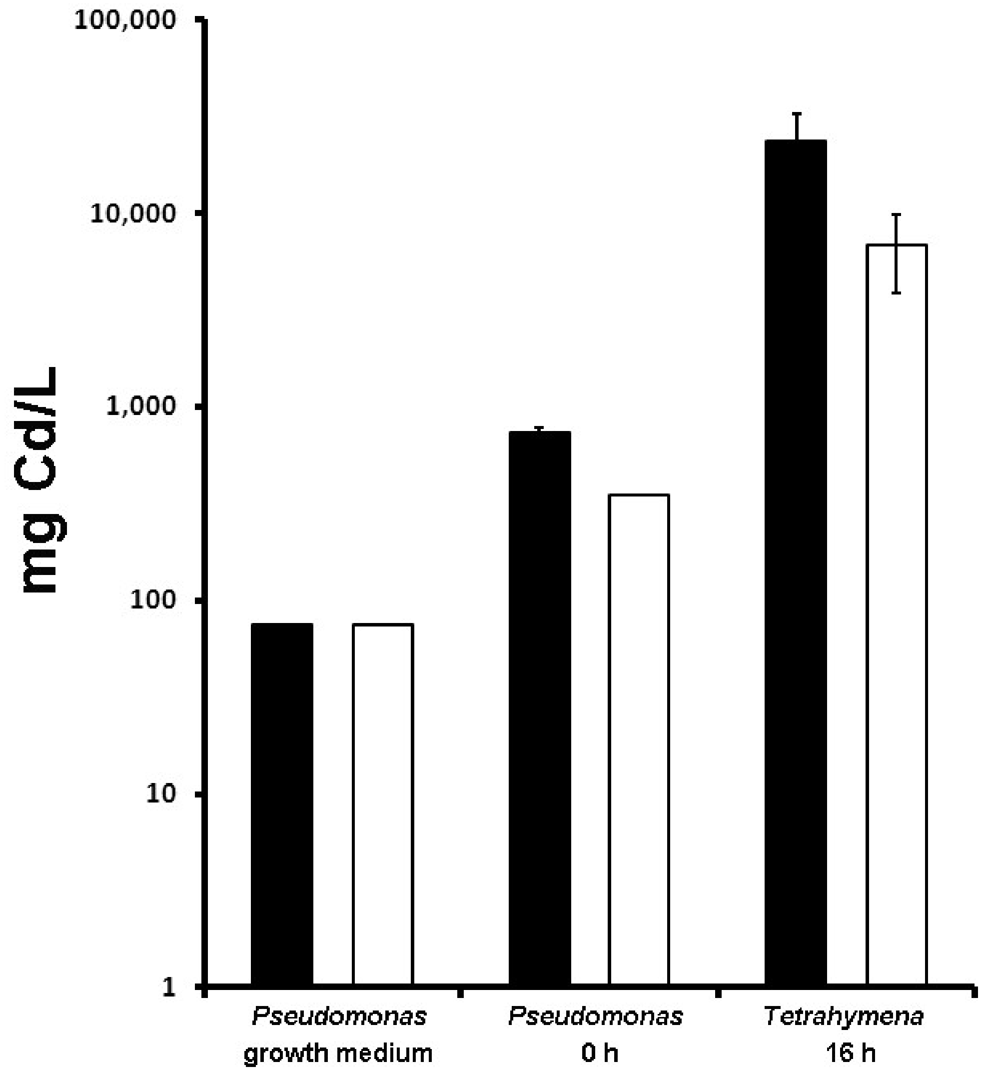
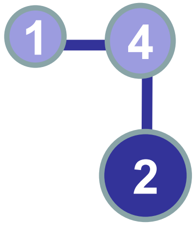
QD & Cd(II) bioaccumulate & biomagnify



(Werlin, Priester, Mielke, Stoimenov, Jackson, Stucky, Cherr, Orias, Holden, *in review*)



Potential Effects of MeOs to Marine Phytoplankton

1 — 4 — 3

- TiO_2, ZnO
  - Industrial
  - 10 to 1000 $\mu g\ L^{-1}$
- Marine water
  - Low TOC, high ionic strength
- Phytoplankton
  - growth rate
  - Yield
  - DEB modeling

TABLE 1. Physicochemical Characteristics of the Metal Oxide Nanoparticles

properties	technique	unit	TiO_2 Evonik 4168063098	CeO_2 Meliorum 121008	ZnO Meliorum 121008
primary size	TEM[a]	nm	27 ± 4	rods: (67 ± 8) × (8 ± 1) (≤10% polyhedra: 8 ± 1 nm)	24 ± 3
particle size in DI water	DLS[a]	nm	194 ± 7	231 ± 16	205 ± 14
phase and structure	XRD[a]		82% anatase and 18% rutile	100% ceria cubic	100% zincite hexagonal
shape/morphology	TEM[a]		semispherical	rods (≤10% Polyhedra)	spheroid
EPM in 1 mM KCl	zetaPALS[a]	10^{-8} m^2 V^{-1} s^{-1}	2.37 ± 0.06	2.19 ± 0.04	1.83 ± 0.11
purity	TGA[a]	wt.%	98.03	95.14	97.27
moisture content	TGA[a]	wt.%	1.97	4.01	1.61

[a] Transmission and scanning electron microscopy (TEM), dynamic light scattering (DLS), X-ray powder diffraction (XRD), isoelectric point (IEP), electrophoretic mobility (EPM), and thermogravimetric analysis (TGA) were done by the UC-CEIN at UCLA . [2] Brunauer–Emmett–Teller analysis (BET) was conducted by Dr. Ponisseril Somasundaran's lab at Columbia University.

IRG 1: Characterizes Zn0, TiO_2, CeO_2

Environmental Toxicology & Chemistry, Vol. 27, No. 9, pp. 1825–1851

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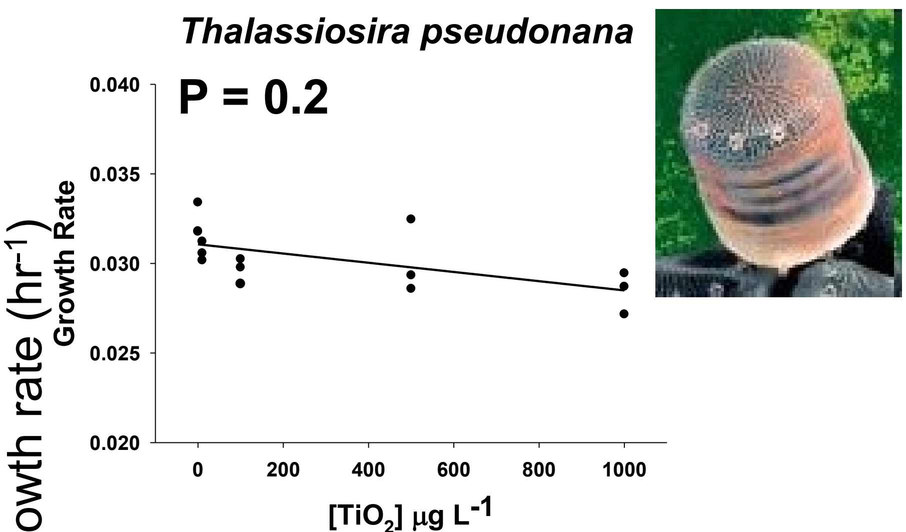
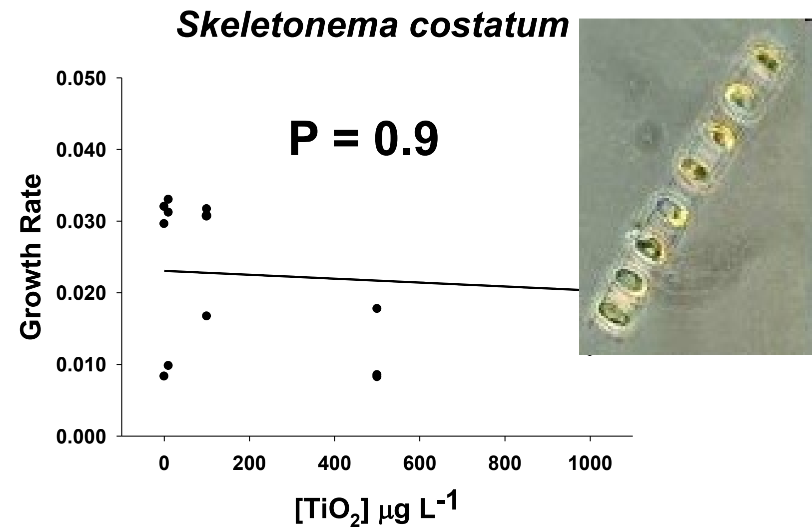
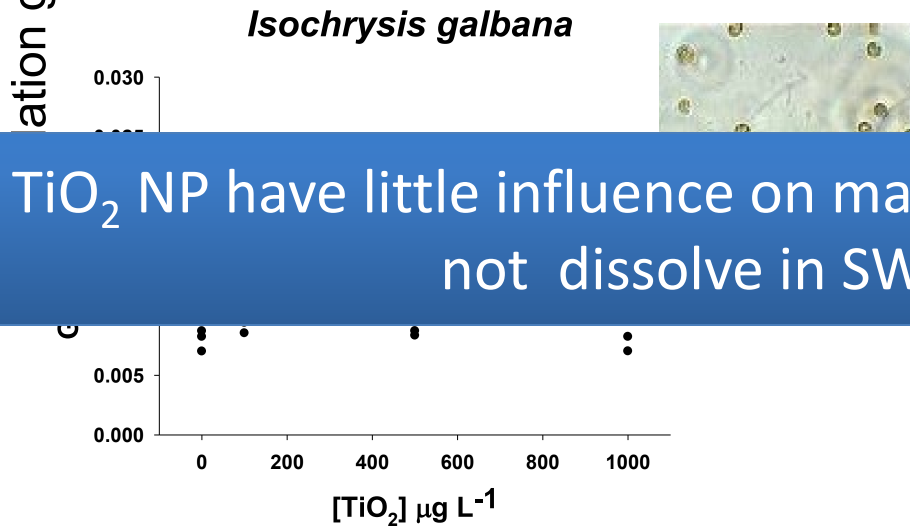
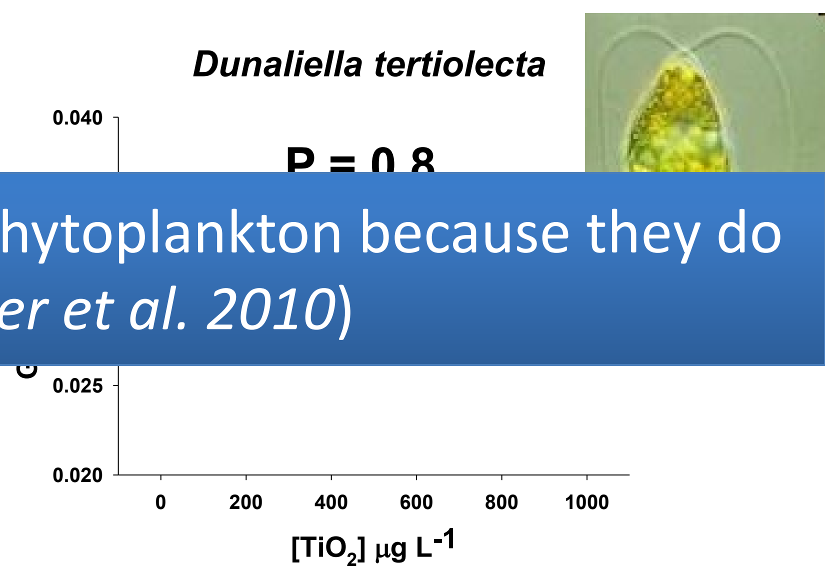
No growth inhibition of marine phytoplankton by TiO_2



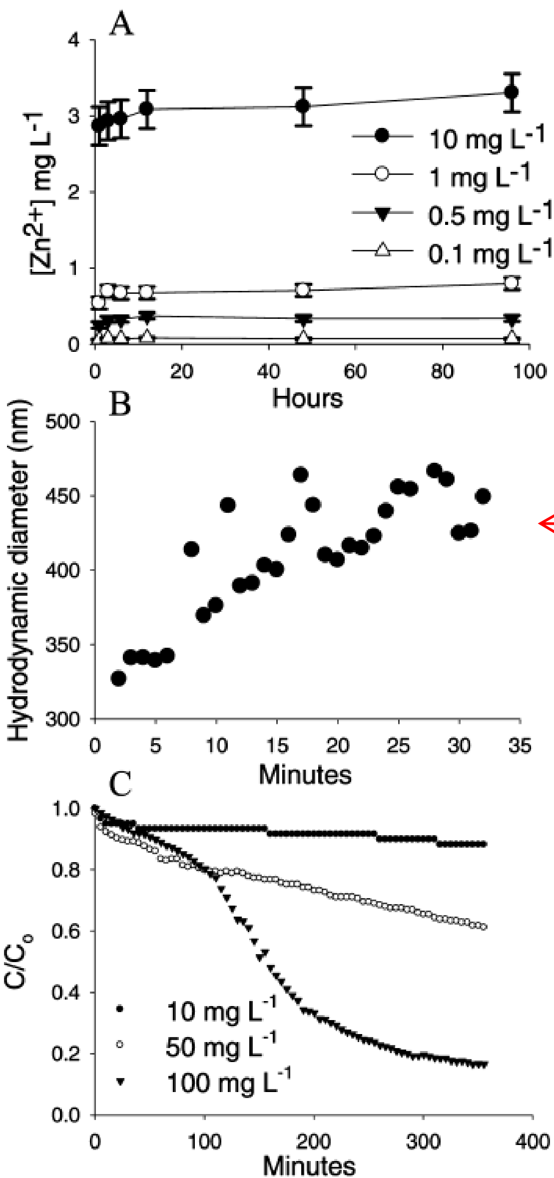






TiO_2 NP have little influence on marine phytoplankton because they do not dissolve in SW (*Miller et al. 2010*)

1 — 4 — 3



ZnO:

dissolves,

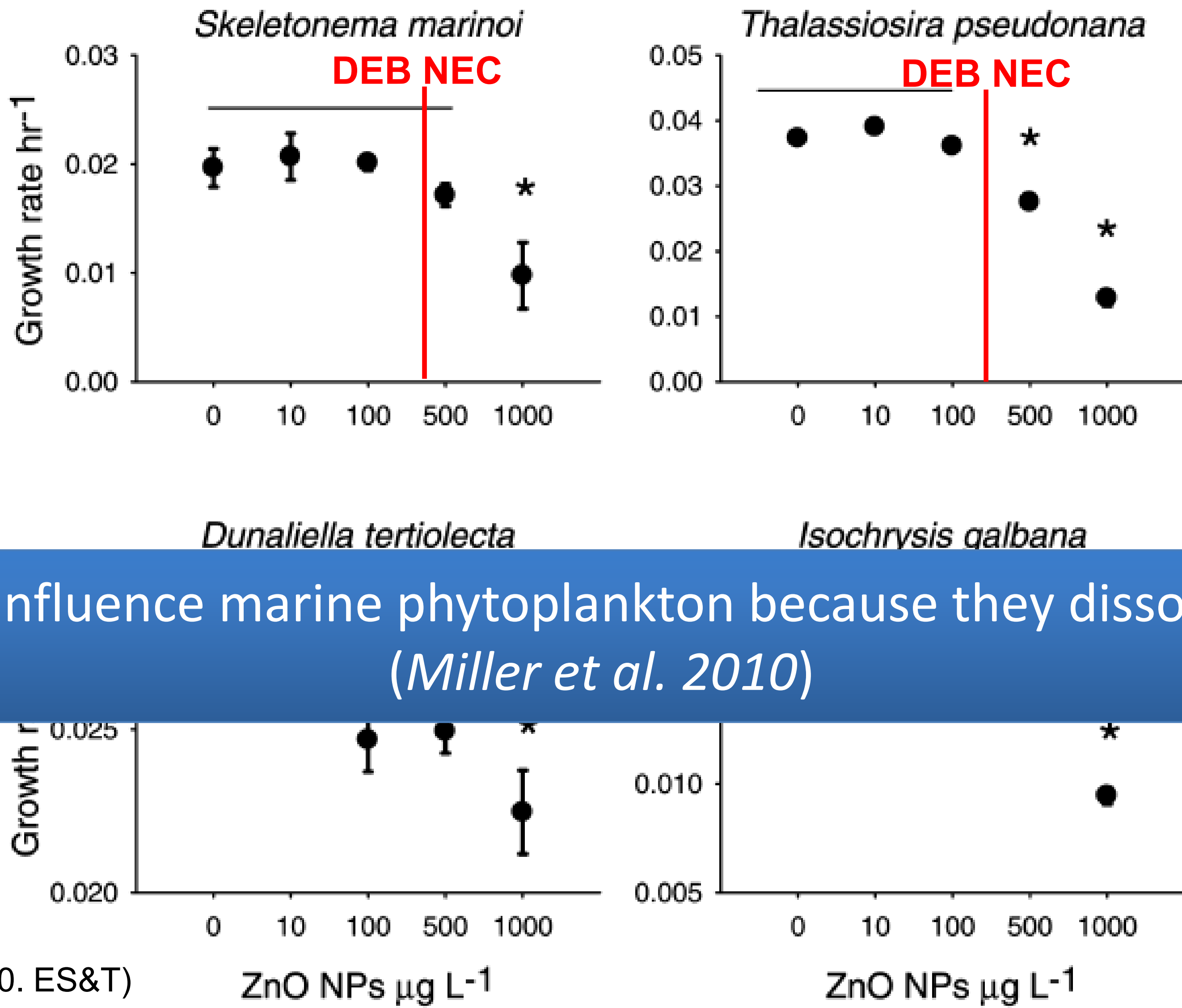
aggregates

settles

(Miller et al. 2010. ES&T)

Toxicity of ZnO to marine phytoplankton

1 — 4 — 3

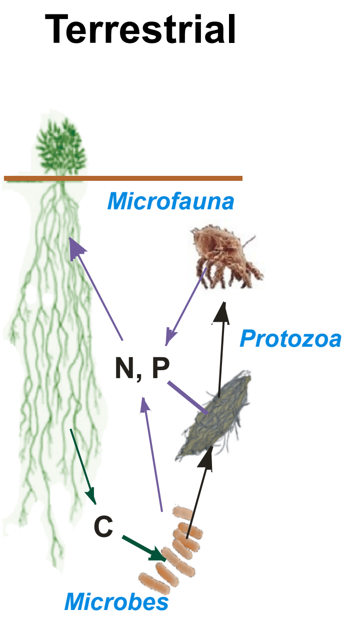


ZnO NP influence marine phytoplankton because they dissolve in SW (*Miller et al. 2010*)

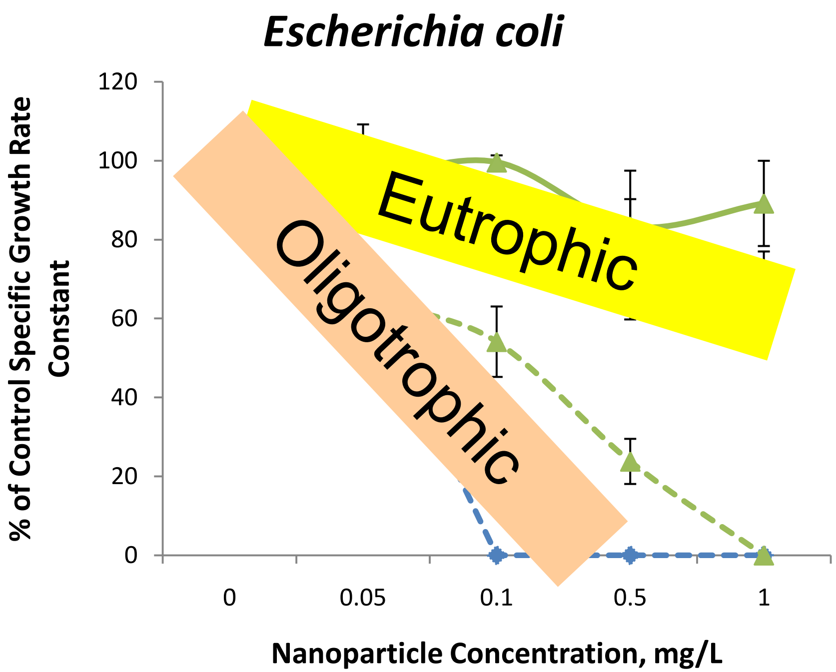
(Miller et al. 2010. ES&T)

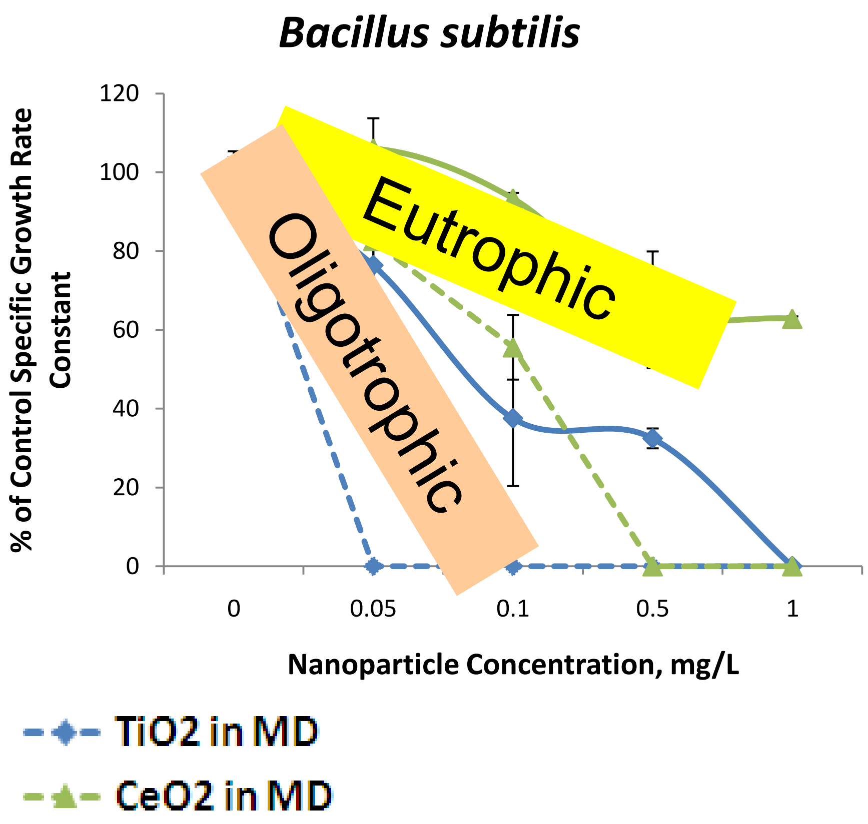
Effects of MeOs to Bacteria and Plants

- TiO_2, ZnO, CeO_2
  - Industrial
- Lab cultivation
  - LB media
  - MMD media
- Bacteria
  - Growth, association
- Plants: soybean
  - MeO integrity, plant growth, genotoxicity



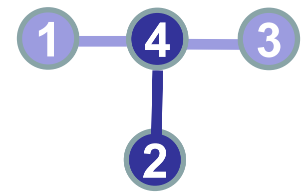
Bacteria Growth Decreased w/ nano-MeOs; Minimal Medium Accentuates

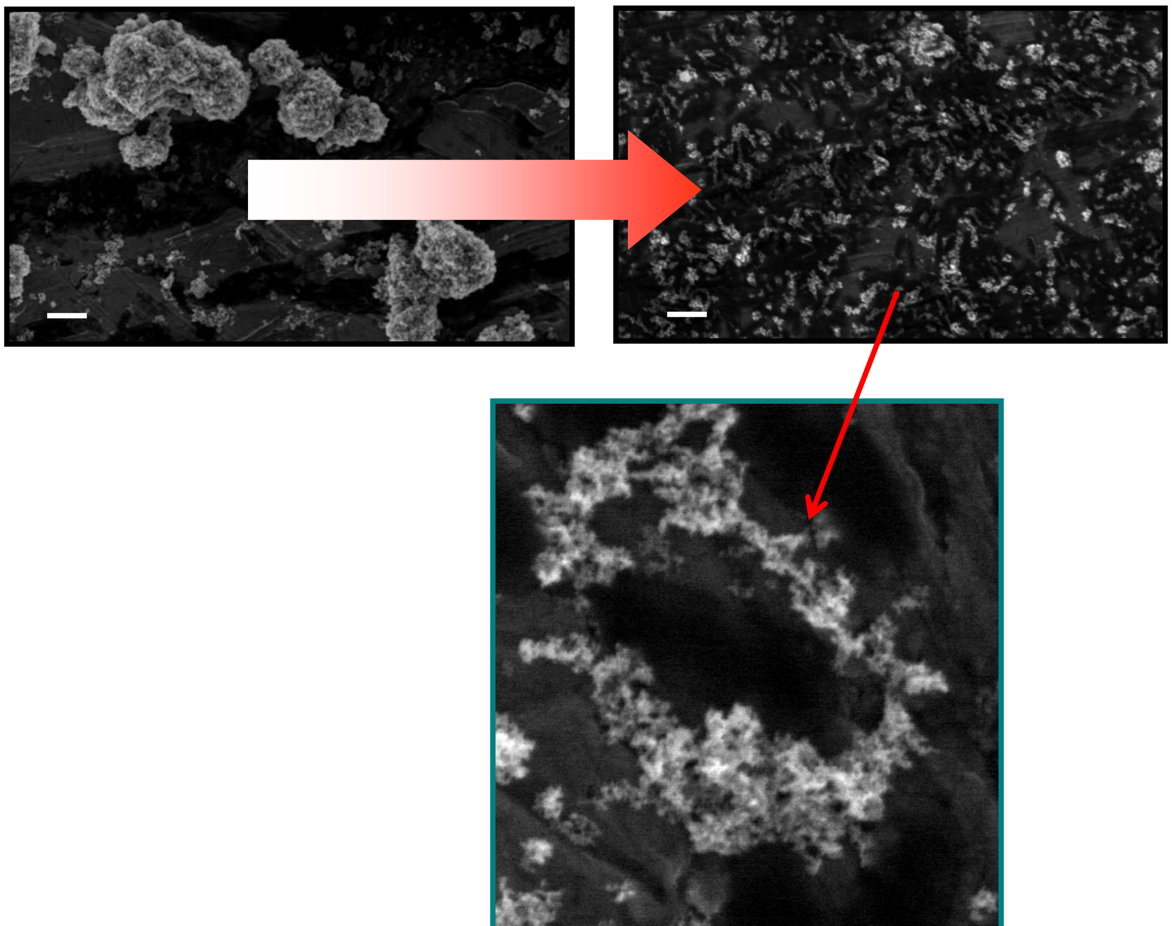


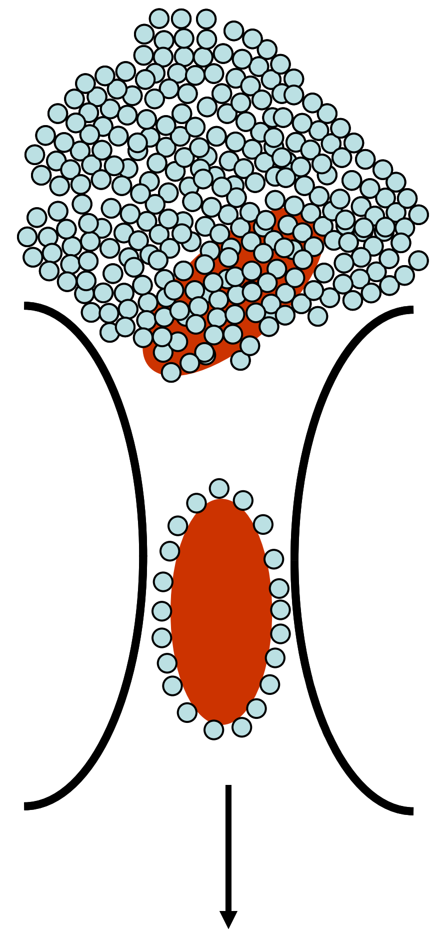


(Vukanti et al. in preparation)

Pseudomonas Disperses nano-TiO_2 Agglomerates







(Horst et al. 2010. in review)

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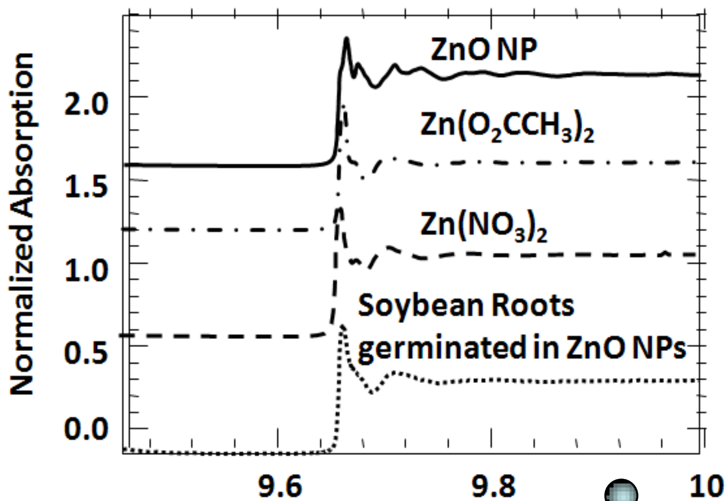
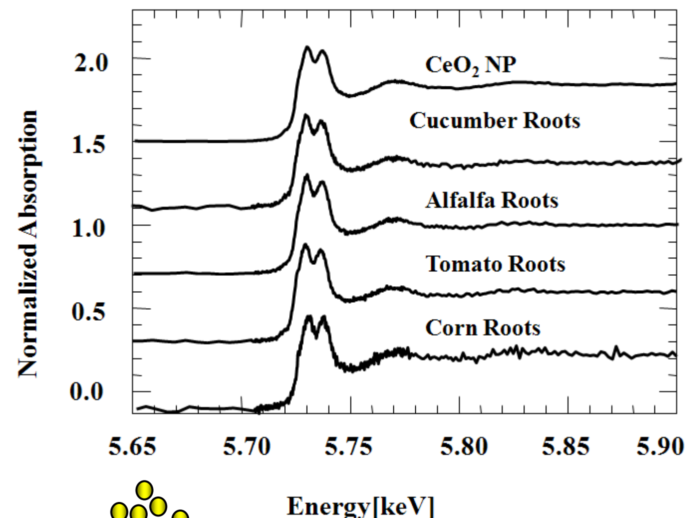
Differential Processing of ZnO and CeO_2 in Soybean Plants

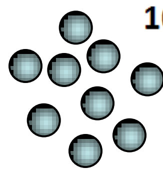
ZnO XAS results



Gardea-Torresdey (Univ. Texas- El Paso)

CeO_2 XAS results





ZnO NPs were biotransformed

??

$Zn(OH)_2$?

Zn^{2+} ?

ZnO

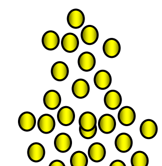
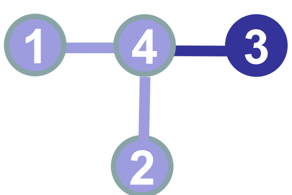


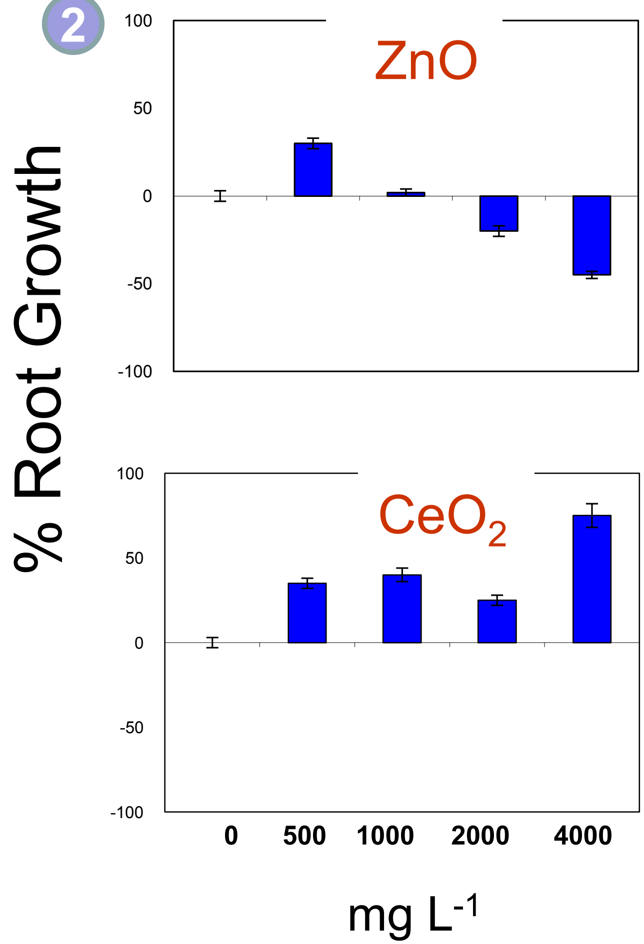
Photo: G. de la Rosa

CeO_2 remained Unchanged and taken up in roots

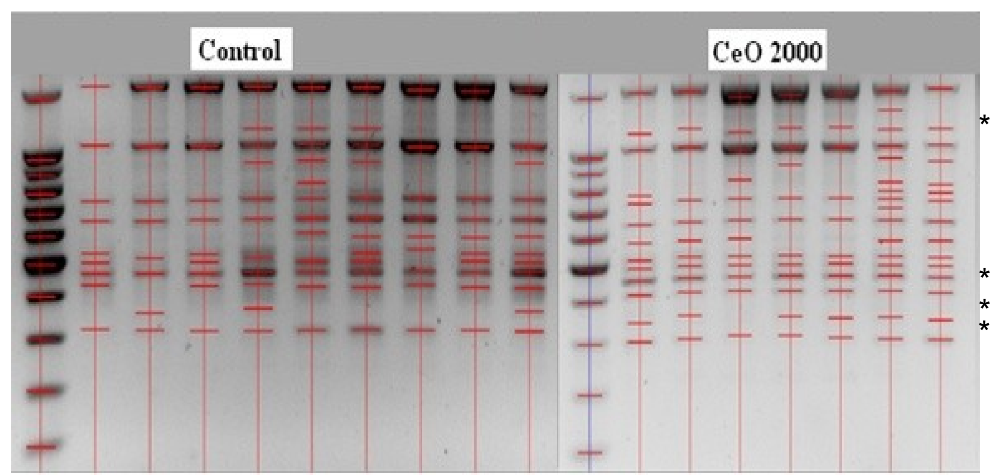


Lopez-Moreno et al. 2010. ES&T

Root growth reduction and genotoxicity in soybean plants exposed to ZnO and CeO_2 NPs



- ZnO NPs reduce root growth while CeO_2 NPs increase root growth
- CeO_2 is genotoxic to soybean. Four new DNA bands appeared in plants treated with 2000 mg CeO_2 L^{-1}



Lopez-Moreno et al. 2010. ES&T

Summary of Talk

- UC CEIN ecotox approach:
  - characterize ↔ expose, add complexity, resolve effects origins
  - Ongoing: adapt to HTS platform
- Results
  - Differential fates and effects of MeO NPs
    - Media- and organism-related
    - ZnO dissolution appears important
  - Effects of bacteria on MeO agglomerates
  - Evidence for biomagnification (CdSe QDs)

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UC TSR&TP NSF /EPA UC CEIN
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